LEVELS OF RADIUM AND URANIUM IN GEORGIA PUBLIC WATER SYSTEMS

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INTRODUCTION

Public water systems in Georgia, in common with those throughout the U.S., are analyzed for radioactive materials and other pollutants before being placed into operation and then at 4-year intervals. This program is undertaken nationally under the Safe Drinking Water Act (P.L. 93-523) and here under the Georgia Safe Drinking Water Act of 1977 (Act No. 231). In accord with the pertinent regulations (Office of Water Supply, 1976), 8,404 samples from 1,612 systems in Georgia have been analyzed for gross alpha particle activity and as required for radium-226, radium-228 and uranium in this laboratory since 1979. This report summarizes these results to mid-1990 in order to indicate the areas in Georgia where elevated levels of radionuclides are found in water systems.

Incomplete data from state programs suggested several years ago that 500 of 60,000 systems in the U.S. had radium-226 plus radium-228 levels that exceeded the maximum contaminant level (MCL) of 5 picocuries per liter (pCi/L) (Milvy and Cothern, 1990). Mean concentrations were estimated to be 0.4 pCi/L for radium-226 and 0.7 pCi/L for radium-228. No MCL for uranium has been specified, hence uranium analyses are only required for the relatively few samples that have a gross alpha particle activity in excess of 15 pCi/L. The same authors estimated a mean uranium concentration of 1.8 pCi/L. The authors also estimated radiation dose equivalents in mrem and mean lifetime risks from ingesting these radionuclides at a drinking water concentration of 1 pCi/L. Respectively, these are 3 mrem per year and 1×10^{-5} for each radium isotope, and 0.5 mrem per year and 0.2×10^{-5} for natural uranium.

A county-by-county survey of the U.S. based on measurements and the geological characteristics of aquifers predicts elevated groundwater levels of radium-226 in the mid-Coastal Plain and the Piedmont of Georgia, and of radium-228 in the Piedmont just north of the Fall Line (Michel, 1990). In a national survey of groundwater supplies, no samples among 23 in Georgia exceeded 5 pCi/L for combined radium, and one sample was above 15 pCi/L for uranium (37 pCi/L in the Piedmont) (Longtin, 1990). In a more extensive survey of uranium in water, 5 samples of 1,700 from Georgia were above 15 pCi/L, with a maximum of 288 pCi/L, all in the Piedmont (Drury et al., 1981).

In this report, the county locations are given for samples in which radium-226 or radium-228 exceeded 5 pCi/L, or uranium exceeded 15 pCi/L, and any patterns of elevated levels are related to physiographic provinces and geological characteristics. The report follows earlier publications that presented the data as of mid-1981 (Cline et al., 1983) and the end of 1983 (Kahn et al., 1984), for approximately 1,400 and 4,000 samples, respectively. The results given are mostly averages for two cycles of analysis, but also include initial analyses and frequently repeated analyses for systems with slightly elevated radium levels; note that some values are for wells which are now closed or were never used for water supply.

PROCEDURE

The water sample, a composite of four quarterly collections or a single collection, is acidified with 4 ml concentrated $HN0_3$ per 3.8 liters and then analyzed. The specified screening system (Office of Water Supply, 1976) is as follows: gross alpha particle activity is determined; if it exceeds 5 pCi/L, radium-226 is measured, and if this measurement exceeds 3 pCi/L, radium-228 is measured. If the gross alpha particle activity exceeds 15 pCi/L, uranium is measured. The analytical methods and detection limits are as described (Cline et al., 1983) except that, since mid-1984, uranium is measured radiometrically, by counting alpha particles after chemical uranium separation. Earlier, it was measured chemically and the result was converted to uranium-238 activity and then multiplied by two on the assumption that uranium-234 was in equilibrium.

Screening criteria in the laboratory were more conservative than specified, in that radium-226 was measured if the gross alpha particle activity plus the 2 sigma error could have equalled 5 pCi/L; radium-228, if the radium-226 activity plus 2 sigma could have equalled 3 pCi/L; and uranium, if the gross alpha particle activity plus 2 sigma could have equalled 15 pCi/L. In addition to new supplies, routinely monitored supplies, and repeat analysis of water above the MCL, some special water supplies were also submitted, for example, to test the possibility of using water as a public supply.

For the purpose of this report, data from each system were averaged. In some instances, several values for a system were obtained for different sources, e.g., where a system is supplied by several wells or new sources replaced old ones.

RESULTS AND DISCUSSION

Of the 1,612 systems monitored during the 11-year period, five percent exceeded the MCL of 5 pCi/L for combined radium-226 and radium-228. All of these systems, as well as all systems that supplied water with elevated radionuclide concentrations shown in Table 1, used ground water; no elevated levels of the three radionuclides were found in the 131 active surface water systems, which are mostly in the Piedmont region. The highest concentrations were 196 pCi/L for radium-226, 27 pCi/L for radium-228, and 860 pCi/L for uranium.

Table 1. Number of Public Water Systems in Georgia with Elevated Radioactivity Levels

Type of analysis	No.	Number exceeding pCi/L		
		5	15	50
gross alpha	1612	258	95	35
Ra-226	373	61	12	4
Ra-228	123	12	1	0
combined Ra	123	83	13	4
uranium	95	--	50	21

Compared to the information obtained after the first 4-year cycle of analysis (Kahn et al., 1984), 133 additional systems are reported here, with twice as many analyses and approximately 4 times as many elevated levels. Most of the additional elevated levels were for newly drilled wells.

Wells with elevated uranium levels are all in the Piedmont region, as shown in Figure 1, extending in a broad band from the Savannah River southwest to the Alabama border. These wells generally penetrate metamorphic or granitic bedrock that has somewhat

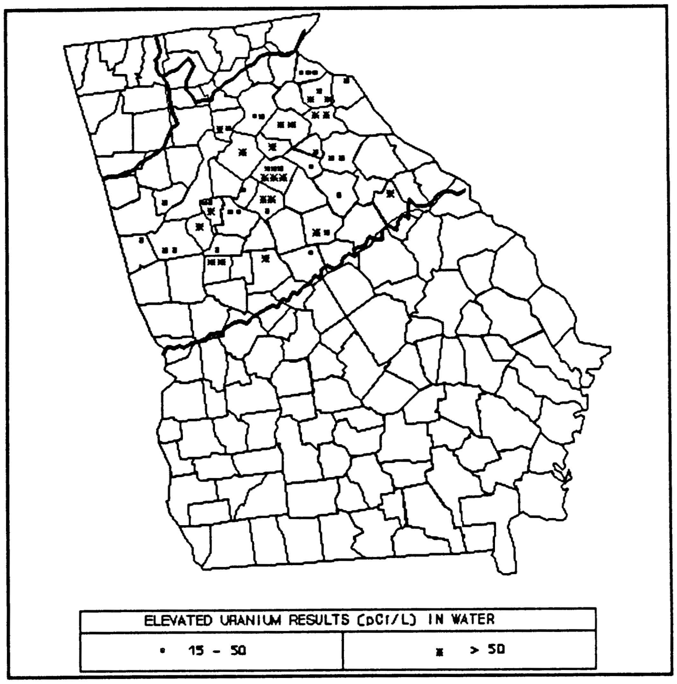

Figure 1. Elevated Uranium in Public Water Systems in Georgia

elevated uranium concentrations. In at least some parts of this region, redox conditions permit oxidation of uranium to its more soluble hexavalent uranyl form, and water has the pH and bicarbonate concentration range to support solubility (Butler, 1990). Approximately 85 percent of groundwater systems in the Piedmont have uranium levels below 15 pCi/L. No elevated levels were found in the Ridge and Valley region to the northwest, the Blue Ridge region to the north, or the Coastal Plain region to the south.

Many elevated radium-226 concentrations, shown in Figure 2, are associated with elevated uranium levels. This is not unexpected because radium-226 is a radioactive decay product in the uranium-238 chain, with 1 radium-226 decay for each two uranium decays at equilibrium. Radium-226 concentrations generally were considerably lower than one-half the uranium concentrations, however, as shown in the plot of individual measurements of radium-226 and uranium for samples with uranium levels above 15 pCi/L, in Figure 3. The straight line of best fit (shown as a curve on the logarithmic plot) of radium-226 vs. uranium has a correlation coefficient of only 0.29. Presumably a lesser fraction of radium-226 than uranium generally remains dissolved in water, but solubility conditions near the wells vary widely.

Elevated radium-226 levels are also found in wells in the Coastal Plain, south of the Fall Line that separates the Piedmont from this region. The source may be phosphate minerals, mined in Florida and coastal regions northeast of Georgia, which have associated uranium minerals.

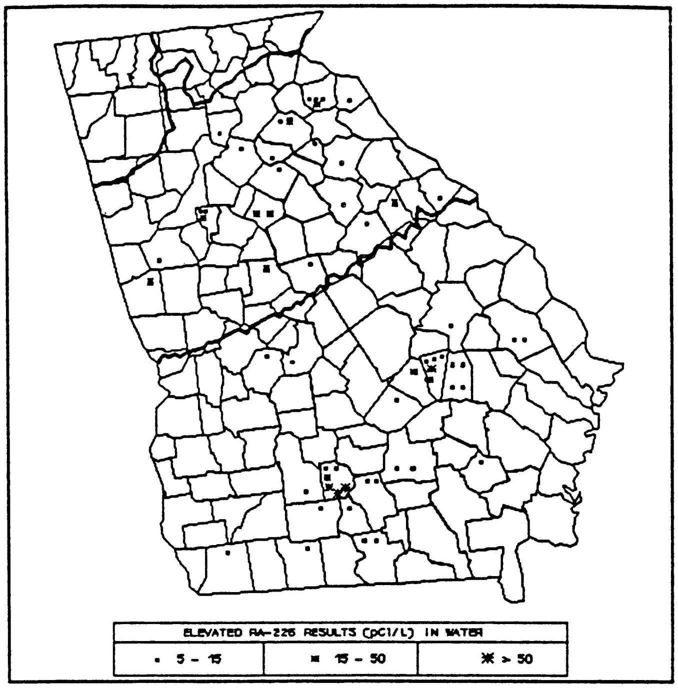

Figure 2. Elevated Radium-226 in Public Water Systems in Georgia

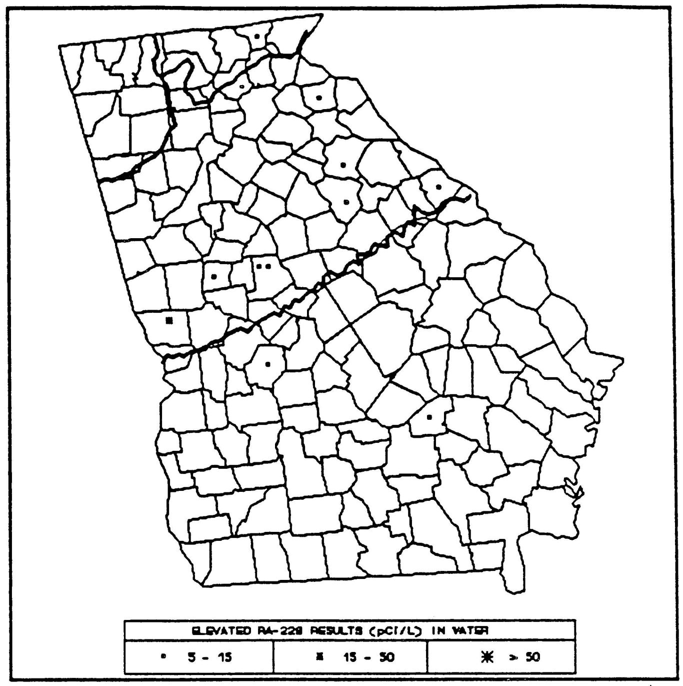

Figure 4. Elevated Radium-228 in Public Water Systems in Georgia

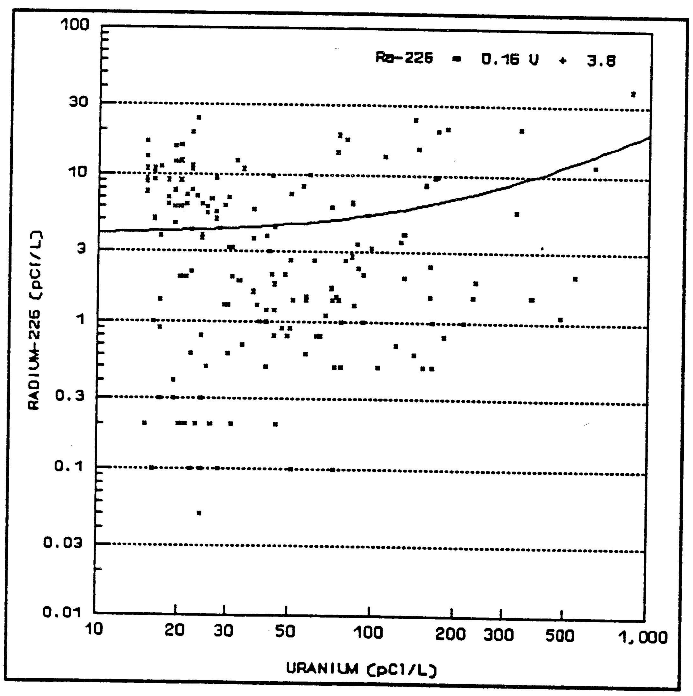

Figure 3. Radium-226 vs Elevated Uranium in Public Water Systems in Georgia

Reducing conditions apparently keep uranium in its insoluble tetravalent state. The band of elevated radium-226 levels from the Savannah River southwest to Florida, shown in Fig. 2, has been associated with the Apalachicola Embayment-Gulf Trough, in which area some wells cased to the top of the Floridan aquifer have elevated radium-226 concentrations (Gorday and Kellam, 1989).

Elevated radium-228 levels in ground water occurred only infrequently, as shown in Fig. 4. Six of the 12 systems with elevated radium-228 levels were in counties just above the Fall Line. Elevated values at a similar location in South Carolina were attributed to detritus deposited after transport from upland ore bodies with elevated thorium levels (Michel and Moore, 1980). Because the present screening system only activates radium-228 analysis when radium-226 is detected as described above, the information on locations for elevated radium-228 may well be incomplete.

The requirement in the regulations that water systems that exceed the MCL be reanalyzed monthly until the situation is corrected resulted in repeated measurements at elevated levels that provide some indication of the variability of radium-226 concentrations. Of 14 systems that were analyzed between 7 and 41 times, values for 9 systems had standard deviations between 10 and 25 percent, while those for the others were as high as 45 percent. All systems with the larger standard deviations had one or two outlying values that suggested (although this could not be documented) that more than a single source of water had been sampled.

CONCLUSION

Monitoring radioactivity levels in Georgia public water systems during the past eleven years has shown that about 5 percent of the systems have combined radium-226 and radium-228 above maximum contaminant levels. All of the elevated systems used groundwater sources. Radium-226 at elevated levels was found in two regions -- the Piedmont, and a central area in the Coastal Plain. Radium-228 at elevated levels was found only in a few locations, notably in the Piedmont just above the Fall Line. Uranium, for which at present there is no MCL, occurred at concentrations above 15 pCi/L only in the Piedmont, in about 15 percent of the groundwater systems.

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